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THE PHOTOCHEMISTRY OF THE SENSITIVITY OF ANIMALS TO LIGHT[1]

I

AN analysis of sensory stimulation, in order to be objective, must take its data from the relations between the properties of the stimulating agent and those of the responses of the animal. If the analysis is to be quantitative as well as objective, not only should the response be a qualitatively invariable reflex but, together with the source of stimulation, it should be capable of precise and easy control.

There are a number of animals which possess such characteristic responses. Typical of these are the ascidian, *Ciona intestinalis* and the long-neck clam, *Mya arenaria*. Both of these animals, when exposed to light, respond by a vigorous retraction of the siphons. It has therefore been possible to investigate quantitatively the properties of their photic sensitivity, and as a result to propose an hypothesis which accounts for this type of irritability in terms of an underlying photochemical mechanism.

I propose now to describe briefly the evidence which has been accumulated in this connection, and to present the outstanding features of the proposed hypothetical mechanism.

II

The photosensory activities of these animals possess four striking and important properties. (1) When exposed to light, the animal

[1] Delivered at the Symposium on General Physiology held by the American Society of Naturalists on December 30, 1920, at its Chicago meetings. The paper was illustrated with a number of charts which are not reproduced here. They may be found, together with the data on which this summary is based, in a series of articles in the *Journal of General Physiology* from 1918 to the present time.

responds only after a measurable interval, which is usually longer than one and a half seconds. This interval is called the reaction time. (2) The animals will respond to light only when there has been a decided increase in its intensity. (3) Once a response has been secured to a given illumination, the continued application of the same intensity fails to produce any additional effect. (4) If, following this, the animal is placed in the dark, it very soon recovers its sensitivity to the light which had previously become ineffective.

It is apparent that these four characteristics are not confined merely to these two species of animals. They belong generally to all animals which are sensitive to increased illumination. Their analysis is therefore of more than immediate interest. Their presence and their quantitative aspects have determined the nature of the hypothesis proposed, and they in turn find their explanation in terms of the hypothesis. It will therefore be well to consider these four outstanding characteristics in greater detail.

III

The reaction time is the interval from the beginning of the exposure to the beginning of the response. In *Ciona* this may vary from 2 to 10 seconds, and in *Mya* from 1.5 to 4 seconds, depending on circumstances such as temperature, intensity of light, and duration of exposure. If these are kept constant, the reaction time is constant.

Fortunately this reaction time is made up almost entirely of the time lost in the sense organ. For example, mechanical stimulation produces the same reflex as illumination. Yet the retraction of the siphons occurs so rapidly that it is not possible to measure it with a stop watch. The adjustor and effector processes, therefore, take almost no measurable time, and the reaction time is confined to the processes which take place in the receptor. This is, to say the least, highly convenient.

The reaction time, however, is not a simple interval. The total exposure to light, which it represents, is not necessary. If the animal is exposed for, say, half the reaction time, it will still respond *in the dark* at the end of the usual reaction time. By proper methods it is possible to reduce the exposure and at the same time to measure the reaction time. It is found that for each intensity of light there is a minimum exposure which will cause a response at the end of the usual reaction time. This short exposure is the sensitization period. Exposures longer than the sensitization period make no change in the duration of the reaction time; exposures shorter than the sensitization period prolong the reaction time, as will presently be described. That portion of the reaction time during which the animal is in the dark, or during which the exposure to light is not necessary, is called the latent period. Normally, therefore, the reaction time is composed of two parts: a sensitization period and a latent period.

The whole matter is strikingly illustrated with *Mya*. Here the sensitization period is extremely short. With a strong light it is only a few hundredths of a second long, whereas the latent period comprises most of the reaction time, which in such a case is about one and a half seconds.

The sensitization period varies with the intensity. The latent period however, provided certain conditions are maintained, is constant for all intensities. At room temperatures the latent period for *Ciona* is 1.76 seconds; for *Mya* it is 1.31 seconds. Since it is our purpose to study the quantitative aspects of this photic sensitivity, it is apparent that the analysis of the reaction time into its two constituents is of first rate significance. The composition of the reaction time was first discovered with *Ciona*, and it immediately opened a hitherto inaccessible field of investigation.

IV

The second characteristic of the sensitivity of these animals is the fact that they will respond to light only when it is increased. This initial action of the light must be on a photosensitive substance contained in the

sense organ. It is necessary to determine whether this action of the light on the sensory process possesses the ordinarily well-demonstrated characteristics of photochemical reactions. Photosensitive chemical reactions have been studied extensively, and certain of their properties have been found to be commonly distributed. One of these is that a definite quantity of radiant energy is associated with a definite photochemical effect. This is the well known Bunsen-Roscoe law, which states that to produce a given effect the product of the intensity and the time of exposure of the light is a constant.

Tested by this standard, the action of light in the sensory responses of *Ciona* and *Mya* is photochemical in nature. With *Ciona,* in the production of a response, the sensitization period varies inversely with the intensity, and their product is constant and equal to 4,746 meter-candle-seconds. The same is true for *Mya.* To produce the minimum stimulating effect the intensity must vary inversely as the exposure, the product of the two being in this case only 5.62 meter-candle-seconds.

Another common property of photochemical reactions is that they possess a low temperature coefficient. Whereas ordinary chemical reactions are markedly accelerated by an increase in temperature, photochemical reactions proceed at pretty much the same rate over wide ranges of temperature. Experiments show that the temperature coefficient for the action of light on the sensory activity of *Mya* is 1.06 for a rise of 10° C. This value is so characteristic for endo-energetic photochemical reactions that, combined with the applicability of the Bunsen-Roscoe law, it can lead to but one conclusion. That is that the initial effect of the light in photic stimulation is a rather simple photochemical phenomenon. These results further indicate that in order to produce a photosensory effect a definite amount of a photosensitive substance must be broken down by the light.

V

The third point which was made with regard to the sensory responses of these animals is that the continued application of the light fails to elicit any additional effect. This has been tested with intense sunlight and with artificial light of over 10,000 meter-candles intensity. The result is always the same. After the first retraction of the siphons, the animal comes into sensory equilibrium with the light. The siphons are slowly extended, and the animal appears to act as if there were no light present.

This brings us to the fourth characteristic of photic sensitivity—the one which has served as the key to the whole situation. This is the fact that when an animal has come into sensory equilibrium with a bright light, it may be made to recover its sensitivity to light by being placed for some time in the dark. The rate at which this recovery takes place is of significance, and has been carefully investigated in the case of *Mya.*

An animal is exposed to an intense light for an hour. It is then suddenly darkened, and at regular intervals its sensitivity is determined by measuring the reaction time to a light of low intensity. What one finds is this. For about three minutes the animal is still insensitive to the particular intensity used. On the fourth minute its first response appears. The reaction time when measured at this time is nearly twice as long as usual. Measured at regular intervals, the reaction time is found to decrease continuously during the next thirty-five minutes. At first this decrease is rapid, then slow, until after thirty-five minutes or so it ceases entirely, and the reaction time is at its minimum for that intensity.

The course of dark adaptation is very orderly. It is similar in the case of *Ciona,* except that it is much slower, requiring about three hours for completion.

What is the significance of these regular changes? Physically they mean that during dark adaptation the quantity of light required for a response is much greater than normal, and that this quantity decreases at first rapidly, then more slowly. The effect of the light we have shown to be the photochemical decomposition of a sensitive sub-

stance in the receptor. Therefore the amount of decomposed photosensitive material necessary for a response during dark adaptation is at first large, and gradually becomes smaller and smaller until it reaches the normal amount for that intensity.

VI

These phenomena, and many others, can be explained in terms of a simple hypothesis. In producing sensory equilibrium, the light decomposes a photosensitive substance, and at the same time causes a loss of sensitivity. The removal of the light results in a characteristic return of sensitivity. This is probably because new photosensitive material is being formed. If we assume that the action of the light is to break up the sensitive material into its precursors, and that in the dark these precursors reunite to form the sensitive substance, all of our data may be explained in terms of the kinetics and dynamics of chemical and photochemical reactions whose general properties are well known and mathematically predictable.

Consider the kinetics of the formation of a sensitive substance from its precursors. The velocity of reaction at any moment will be proportional to the concentration of the precursors. Therefore these will disappear at first rapidly, and then more slowly according to the well-known expression

$$-\frac{dx}{dt} = k(a-x)^n,$$

where $(a-x)$ represents the concentration of precursors, and n the order of the reaction, the other symbols having their usual meaning.

It is certain that the reaction time, and therefore the amount of photochemical action necessary for a response, is not proportional to the concentration of sensitive substance in the sense organ, because during dark adaptation the former decreases while the latter increases. Moreover, it becomes apparent on second thought that the sensitive substance as such is not the effective agent; it is only after it has been decomposed by the light into something else that it can produce its effect. It is therefore more likely that the amount of decomposition represented by the reaction time (more accurately, by the sensitization period) will depend not on the concentration of sensitive substance, but on the concentration of its precursors.

Let us assume this to be true. The changes in the reaction time during dark adaptation should therefore parallel the progress made in the disappearance of precursor material during their combination to form the sensitive material. A superficial resemblance between the dark adaptation curve and the isotherm of a chemical reaction is at once apparent. The resemblance however is more than superficial. The curve which best fits all of the data on dark adaptation is actually the isotherm of a bimolecular reaction, represented by the expression

$$k = \frac{1}{at}\cdot\frac{x}{a-x},$$

which is the integral form of the equation above when $n=2$; a represents the initial concentration of precursors, x the concentration of sensitive substance at the time t, and $a-x$ is the concentration of precursors at the same time. This means that there are *two* precursors (P and A) whose concentration is decreasing because they are combining to form the sensitive substance S. The process which goes on in the sense organ may then be written

$$S \underset{\text{"dark"}}{\overset{\text{light}}{\rightleftharpoons}} P + A$$

with a full consciousness of the quantitative significance of the expression.

VII

The dynamics of this reversible photochemical reaction account for the prominent characteristics which we have described for the photosensory process. The response to an increase in illumination, the applicability of the Bunsen-Roscoe law, and the low temperature coefficient are all inherent to the light reaction, $S \rightarrow P + A$. Sensory equilibrium corresponds to the well-known station-

ary state which results when the opposing light and "dark" reactions become balanced, and no fresh decomposition products can be formed by the light. Dark adaptation very obviously is a clear function of the unopposed "dark" reaction.

More than this, however. Certain predictions may be made on the basis of this reversible reaction. Several of these have been investigated with complete success. To mention just a simple example: the "dark" reaction, $P + A \rightarrow S$, is an ordinary chemical reaction; its temperature coefficient should therefore lie between 2 and 3. This is equivalent to saying that the temperature coefficient of dark adaptation should lie between 2 and 3 for 10° C. This is precisely what has been found to be true. The temperature coefficient of dark adaptation for *Mya* is 2.4. This concept of a reversible photochemical reaction has therefore been fruitful in accounting for the known properties of photosensory stimulation, and has served to suggest the investigation of other properties. The results of these have in turn corroborated the original explanation.

VIII

So far we have considered the events which take place during the sensitization period only. The photosensory responses of these animals, however, involve the very definite existence of a latent period. In fact, in the case of *Mya,* most of the reaction time is merely latent period and nothing more. Fortunately this part of the reaction time has also yielded to quantitative methods of analysis, and as a result we can now offer an explanation of photoreception which covers not only the sensitization period, but the latent period as well.

At the beginning of this paper, in defining the different parts of the reaction time, I pointed out a significant fact. It is that if the exposure of an animal to light is made shorter than the sensitization period at that intensity, the reaction time—and consequently the latent period—is prolonged. This indicates that there is some interrelation between the two portions of the reaction time. Experiments were therefore made in which animals were exposed for varying periods of time, all less than the sensitization period. It was found that the duration of the latent period varies inversely with the length of the exposure to light.

The latent period, being the interval during which the animal may remain in the dark following the exposure, is certainly not a time during which nothing happens. We may be sure that a process takes place during the latent period which is in some way a vital link in the chain of events between the incidence of the light and the appearance of the response. Whatever this process may be, we can consider its velocity as proportional to the reciprocal of the duration of the latent period. When this is done, we find that the velocity of the latent period process is a linear function of the duration of the initial exposure to light.

During the exposure we know that the photosensitive substance S is decomposed. We may assume that for these extremely small exposures, the photochemical effect is directly proportional to the time of action of the light. It therefore follows that the velocity of the latent period process is a linear function of the photochemical effect during the exposure. In other words, the velocity of the latent period reaction is directly proportional to the concentration of freshly formed precursor substances P and A.

Such a relationship may be explained in several ways. The one finally chosen assumes that during the latent period an inert substance, L, is changed into a chemically active material, T, which then acts upon the nerve to produce the outgoing sensory impulse. This reaction, $L \rightarrow T$, is catalyzed by the presence of the freshly formed photochemical decomposition products, P and A, formed during the exposure to the light. The linear relation between velocity of reaction and concentration of catalyst is a very common one in catalyzed reactions.

In terms of this conception the latent period assumes a position of prime importance in the photosensory mechanism. The latent

period reaction is all set and ready to go, and requires only that the light change S into P and A so that the latter can catalyze the transformation of L into T, which is the end-product of the sensory process. The whole photosensory mechanism may then be summed up in the two reactions

$$S \rightarrow P + A; \quad L \| P + A \| \rightarrow T,$$

in which the symbol $\| P + A \|$ means catalysis by one or both of the precursor substances. The first of the two reactions occurs during the sensitization period; the second during the latent period.

IX

This hypothesis of photoreception is rather concrete. The concreteness of the conceptions has however proved a useful tool in the acquisition of knowledge in this field. Time does not permit the description of experiments designed to test the hypothesis in numerous ways. I can, however, mention just a few to indicate its fruitfulness.

The latent period is assumed to be a simple, chemical reaction, perhaps as hydrolysis or an oxidation. Its behavior with the temperature should therefore follow quantitatively the rule deduced by Arrhenius for the relation between the velocity constant of a reaction and the absolute temperature. This means more than a mere determination of the temperature coefficient for 10 degrees; it means a continuous relationship between temperature and velocity, following certain theoretical considerations. Experiments showed that the reaction $L \rightarrow T$ follows this prediction accurately, and that the value of the constant, $\mu = 19{,}680$, for our reaction is in accord with those usually found for hydrolyses, saponifications, etc., in pure chemistry.

Another test concerns the interrelations between the exposure and the latent period. I have mentioned that the velocity of the latent period reaction is directly proportional to the exposure (t), provided the intensity (I) is kept constant. This may be written

$$V = k_1 t.$$

If now we keep the time of exposure constant and vary the intensity we find that

$$V = k_2 \log I$$

or that the velocity is proportional to the logarithm of the intensity. Ordinary mathematical reasoning indicates that if we combine these two equations—which means experimentally that we vary simultaneously both the time and the intensity—it should be true that

$$V = kt \log I.$$

Experiments prove that this expected relationship indeed holds good.

Still another and perhaps more significant application of the proposed hypothesis has been made. This concerns the dark adaptation of the human eye. A careful analysis of the data of dark adaptation in terms of the principles discovered in these investigations has shown that dark adaptation and protoreception in the human retina are fundamentally similar in principle to the process in *Mya* and *Ciona*. As a result there has been opened up a new field of investigation in retinal photochemistry which may some day enable us to possess a reasonable theory of vision.

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THE MECHANISM OF INJURY AND RECOVERY OF THE CELL[1]

Some of the fundamental ideas of biology are extraordinarily difficult to analyze or define in any precise fashion. This is true of such conceptions as life, vitality, injury, recovery and death. To place these conceptions upon a more definite basis it is necessary to investigate them by quantitative methods. To illustrate this we may consider some experiments which have been made upon *Laminaria,* one of the common kelps of the Atlantic coast.

[1] Address for the Symposium on General Physiology at the meeting of the American Society of Naturalists, December, 1920.

It has been found that the electrical resistance of this plant is an excellent index of what may be called its normal condition of vitality. Agents which are known to be injurious to the plant change its electrical resistance at once. If, for example, it is taken from the sea water and placed in a solution of pure sodium chloride it is quickly injured, and if the exposure be sufficiently prolonged it is killed. During the whole time of exposure to the solution of sodium chloride the electrical resistance falls steadily until the death point is reached; after which there is no further change. If we study the time curve of this process, we find that it corresponds to a monomolecular reaction (slightly inhibited at the start).

This and other facts lead to the assumption that the resistance is proportional to a substance, M, formed and decomposed by a series of consecutive reactions. On the basis of this assumption we can write an equation which allows us to predict the curve of the death process under various conditions. This involves the ability to state when the process will reach a definite stage, *i.e.*, when it will be one fourth or one half completed. This can be determined experimentally with considerable accuracy.

This curve is of practical, as well as of theoretical importance, since it allows us to compare the degree of toxicity of injurious substances with a precision not otherwise attainable. The best way of doing this is to proceed as a chemist might in such cases and express the degree of toxicity by the velocity constants of the reaction (*i.e.*, of the death process) under various conditions.

From this point of view we must regard the death process as one which is always going on, even in an actively growing normal cell. In other words the death process is a normal part of the life process. It is only when it is unduly accelerated by a toxic substance (or other injurious agent) that the normal balance is disturbed and injury or death ensues.

If we wish to put this into chemical terms we may say that the normal life process consists of a series of reactions in which a substance O is broken down into S, this in turn breaks down into A, M, B and so on. Under nomal conditions M is formed as rapidly as it is decomposed and this results in a constant condition of the electrical resistance and other properties of the cell. When, however, conditions are changed so that M is decomposed more rapidly than it is formed the electrical resistance decreases and we find that other important properties of the cell are simultaneously altered.

Hence it is evident that injury and death may result from a disturbance in the relative rates of the reactions which continually go on in the living cells.

It is evident that we can follow the process of death in the organism in the same manner that we follow the progress of a chemical reaction *in vitro*. In both cases we obtain curves which may be subjected to mathematical analysis, from which we may draw conclusions as to the nature of the process. This method has been fruitful in chemistry and it seems possible that it may be equally useful in biology.

If we suppose that resistance depends on a substance, M, it may be desirable to discuss briefly certain assumptions which have been made in regard to it. The protoplasts of *Laminaria* are imbedded in a gelatinous matrix (cell wall) which offers about the same electrical resistance as sea water or dead tissue. Since the electrical resistance of the living tissue is about ten times as great as when it is killed it is evident that the living protoplasm must be responsible for the increased resistance. The living cells consist for the most part of a large central vacuole surrounded by a delicate layer of protoplasm: the sap which fills the vacuole seems to have about the same resistance as the sea water. The high resistance of the living tissue must therefore be due to the layer of protoplasm surrounding the vacuole, a layer so extremely thin as to be comparable to what is commonly called the "plasma membrane." Since the current is due to the passage of ions through

this extremely thin layer of protoplasm[2] it would seem that the electrical resistance may be regarded as a measure of the permeability of the protoplasm to ions. It is of interest in this connection to find that the measurements of the permeability of the protoplasm by a variety of other methods (plasmolysis, exosmosis, diffusion of salts through the tissue, entrance of dyes, etc.) confirm the results obtained by electrical measurement.

In view of these facts the simplest assumption which we can make concerning M is that it is a substance at the surface of the protoplasm which determines the resistance: as M increases in amount and forms a thicker layer the resistance increases, and vice versa.

Tissue which has developed under normal circumstances is found to be rather constant in its electrical resistance. This is of considerable practical importance as it enables us to test material as it comes into the laboratory and to reject any which has been injured or is in any way abnormal.

We may therefore speak of a normal degree of resistance as indicating a normal state of the tissue. If injury occurs and the resistance falls we may consider that the loss of resistance gives a measure of the amount of injury. Thus if the tissue loses ten per cent. of its normal resistance we may say that the injury amounts to ten per cent. This enables us to place the study of injury upon a quantitative basis.

In the case of *Laminaria* we find that if the injury in a solution of sodium chloride amounts to five per cent. the tissue recovers its normal resistance when replaced in sea water. If however the injury amounts to twenty-five per cent. the recovery is incomplete: instead of rising to the normal it recovers to only ninety per cent. of the normal. The greater the injury the less complete the recovery. When injury amounts to ninety per cent. there is no recovery at all.

[2] Some of the current passes between the masses of protoplasm (*i.e.*, in the cell wall) but allowance can be made for this since the relative proportion of cell wall and protoplasm remains unaltered throughout the experiment.

This is of practical interest in view of the fact that in physiological literature it seems to be generally assumed that when recovery occurs it is always complete, or practically so, as if it obeyed an "all or none" law. It is evident that partial recovery may be easily overlooked unless accurate measurements are possible. This may serve as another illustration of the fact that quantitative methods are indispensable in the study of fundamental processes.

It is evident that injury presents two aspects. One is the temporary loss of resistance which disappears, wholly or in part, when the tissue is placed under normal conditions: this may be called temporary injury. The other is the permanent loss of a part of the resistance which is observed after more prolonged exposure: this may be called permanent injury. By exposing tissue for various lengths of time to a toxic solution and observing the amount of recovery each time we may construct a time curve of permanent injury. This curve may be subjected to the same kind of mathematical treatment as the time curve of temporary injury, already discussed. The mathematical analysis leads to the conclusion that if we adopt the scheme $O \rightarrow S \rightarrow A \rightarrow M \rightarrow B$ we must regard temporary injury as due to the loss of M while permanent injury is due to the loss of O. Recovery occurs when the loss of M is replaced by a fresh supply of M derived from O, but if O is itself depleted recovery will be incomplete.

It may be added that an equation has been found which enables us to predict the recovery curves under a great variety of conditions with considerable accuracy.

If we accept the conclusions stated above we are obliged to look upon recovery in a somewhat different fashion from that which is customary. Recovery is usually regarded as due to the reversal of the reaction which produces injury. The conception of the writer is fundamentally different; it assumes that the reactions involved are irreversible (or practically so) and that injury and recovery differ only in the relative speed at

which certain reactions take place. Thus in the series of reactions

$$O \rightarrow S \rightarrow A \rightarrow M \rightarrow B,$$

if the rate of $O \rightarrow S$ becomes slower than the normal, injury will occur, while a return to the normal rate will result in recovery. Injury could also be produced by increasing the rate of $M \rightarrow B$, or decreasing the rate of $S \rightarrow A$ or $A \rightarrow M$.

If life is dependent upon a series of reactions which normally proceed at rates bearing a definite relation to each other, it is clear that a disturbance of these rate-relations may have profound effects upon the organism, and may produce such diverse phenomena as stimulation, development, injury and death. It is evident that such a disturbance might be produced by changes of temperature (in case the temperature coefficients of the reactions differ) or by chemical agents. The same result might be brought about by physical means, especially where structural changes occur which alter the permeability of the plasma membrane or of internal structures (such as the nucleus and plastids) in such a way as to bring together substances which do not normally interact.

In the case of *Laminaria* death may occur in two ways. In the first there is a loss of resistance which continues until the death point is reached, as, for example, in sodium chloride. In the second, as in calcium chloride, there is an increase of resistance followed by a decrease. Both of these methods may be predicted by means of the scheme already outlined.

If we mix sodium chloride with calcium chloride we do not get a result which is merely intermediate for we find that long after death has occurred in pure sodium chloride or pure calcium chloride the tissue still survives in a mixture of these salts (made in certain definite proportions). The facts lead us to assume that both sodium and calcium combine with a constituent, X, of the protoplasm, forming a compound Na_4XCa. According to the laws of mass action we may calculate the amount of this compound which will be formed in each mixture of sodium and calcium chlorides. These calculations indicate that the speed of all the reactions is regulated by the amount of Na_4XCa (it is also found that certain reactions are accelerated by calcium chloride).

This enables us, by means of the equations already mentioned, to predict the time curves of injury and death in mixtures (in addition to those in pure salts) as well as the recovery curves when tissue is transferred from such mixtures to sea water.

It is evident therefore that the theory not only explains why pure sodium chloride and calcium chloride are toxic but also why they antagonize each other in mixtures. Moreover the explanation which it furnishes is a quantitative one, *i.e.*, it shows just what degree of antagonism is to be expected in each mixture.

Extremely interesting results are obtained when the tissue is first exposed to sodium chloride, then to calcium chloride, then to sodium chloride or to sea water and so on. By varying the conditions of the experiment a very complicated set of curves may be obtained. It is rather remarkable to find that all of these may be predicted with considerable accuracy by means of the equations already referred to. A detailed statement of the results will be found in recent papers in the *Journal of General Physiology.*

Throughout these investigations the aim has been to apply to the study of living matter the methods which have proved useful in physics and chemistry. The attempt presented no serious difficulties after accurate methods of measurement had been devised: nor does there seem to be any real obstacle to a general use of methods which lead biology in the direction of the exact sciences.

It is evident that if the facts have been correctly stated such fundamental conceptions as vitality, injury, recovery and death may be investigated by quantitative methods. This leads us to a quantitative theory of these phenomena and a set of equations by which they can be predicted. It may be added that the

predictive value of these equations is quite independent of the assumptions upon which they were originally based.

This investigation of fundamental life processes shows that they appear to obey the laws of chemical dynamics. It illustrates a method of attack which may throw some light upon the underlying mechanism of these processes and assist materially in the analysis and control of life-phenomena.

W. J. V. Osterhout

Harvard University

ISAO IIJIMA

Professor Isao Iijima, head of the department of zoology in the Imperial Uinversity, died of apoplexy at his home in Tokyo on March 14. His father, a Samurai of the Daimyo Inouyé of Shizuoka, was one of those devoted to foreign learning in the decades before the restoration: proceeding to Nagasaki, he studied European ideas through the medium of the Dutch language—later suffering imprisonment on account of these interdicted studies. The son Isao, born Bunkyu-ni-nen (1860), followed the father's footsteps, was early a student of foreign languages and science, and was eager to master physiology and anatomy. So he found his way presently to the Imperial University of Tokyo, which then was beginning its famous career. Here he came under the guidance of the American zoologist, Professor Edward S. Morse, whose inspiration soon turned him from medical studies to pure science. Thereafter he went to Leipsic, where he took his doctorate with Professor Leuckart. Returning to Japan about 1885, he was appointed a member of the faculty of the Imperial University, where he was to remain until the day of his death; in the last years he was also professor in zoology at the Nobles' College, Tokyo. Foreign zoologists will always remember Iijima, side by side with Kakichi Mitsukuri, as taking foremost and genial place in all zoological matters in Japan. His knowledge of the general subject was unusually wide: a fluent lecturer, an attractive personality, he popularized zoology and brought help to it from many sides; for not only was he the trained morphologist, but the old school naturalist as well, bird expert notably, having among his friends collectors and gunners in all part of Japan; his hobby took him everywhere, and as a good shot he was as welcome in the hunting parties of the Emperor as with the pheasant-stalking peasants on the hillside near Misaki—where for many years he spent his summers. Here was the seaside laboratory of his zoological department, and offshore were the great depths of Okinosé (6,000 meters) from which many a red-turbaned fisherman, and Kuma Aoki especially, brought him the rarest of glass-sponges. These Iijima made his life-long study: and he dealt with them in memoirs which, published in the main in the *Journal of the Science College*, are classics, indeed—though Iijima himself would be apt to add, in his joking way, that this was not as great a feat as it seemed, since he was the only life-long specialist in the field! In point of fact, these sponges were poorly represented throughout the world (large museums had sometimes not more than a few small specimens—usually a ragged Hyalonema, or a defective Venus-basket), till the discovery was made of many species, genera, and even families of them in Iijima's district of the Pacific where nature seemed to have taken many pains to keep them alive in an early geological "garden."

In a practical direction Iijima's studies carried him to the culture of "artificial" pearls, and several of his students, the late Dr. Nishikawa especially, developed this industry with great success—having devised new modes of causing the pearl oyster to produce hemispherical, more-than-hemispherical, and in the latest time completely spherical pearls.

Bashford Dean

SCIENTIFIC EVENTS

EX-SECRETARY MEREDITH ON RESEARCH

(*From a correspondent*)

The organization of research is now receiving so much attention that the fear is ex-

pressed that more fundamental considerations are being overlooked. The words of Edwin T. Meredith, former Secretary of Agriculture, may, then, serve as a timely warning. In a statement published under the title "My Year in the Department," in the *Country Gentleman* for February 26, 1921, he points out as requisite for the successful prosecution of research in a large organization these fundamentals: Securing the right kind of men; providing them with adequate appropriations for research; freeing them from irksome restrictions in the expenditure of those funds; and providing for adequate publication of their results. That Mr. Meredith speaks with full appreciation of the importance of research, is shown by his administration and by its straightforward statement in the same article.

Research is the foundation of agricultural progress. Without it most of our agricultural activities could not exist. Our most important methods are based on the results of years of patient investigation. There is no real progress without scientific study applied to everyday problems. So much had been accomplished through research that many people may fall into the error of thinking that not much more work of this character is needed and that the requirements of the day relate merely to the application of knowledge already in hand. Research is more essential now than ever before, and the need does not relate wholly to taking care of the future. We are confronted today with serious problems of the most pressing nature, about which we know very little. . . .

Without minimizing in any degree any of the activities of the department or the other suggestions that have been made for strengthening certain features of the work, I place particular emphasis at this time on the importance of personnel, the value of research and the need of the most intensive study possible of marketing problems.

I place the problem of personnel first. It is the corner stone, you might say, of the whole structure. To secure the right kind of men the department must be able to pay higher salaries, and it must be free from some of the limitations which are now imposed on the expenditure of its appropriations. I am not decrying legal safeguards, which always must be imposed on the expenditure of public money, but I do deplore unnecessary restrictions which result in subordinating good judgment and business-like management to routine and fiscal control.

Appropriations for research are the equipment of the worker, and unless he is properly equipped he can not be expected to get results. And in this connection I regard, as a part of his equipment, funds for publishing the results of his work. Nothing is more discouraging to a scientific worker than to be denied the right to publish the facts he has learned after years of patient investigation.

So much has been written recently of the alleged inefficiency of government workers that it is inspiring to hear, from an executive officer on the eve of his retirement, a quite different statement.

The work of the department, taking it all the way through, is done by as earnest and as able a lot of men and women as any with whom I have ever come in contact. On the whole, they work as many hours a day and as efficiently, I believe, as employees in most private establishments, and they are paid less. Large numbers of them are held to their work by their love for it. Many formerly with the department were offered so much more money in private employment that, in justice to themselves and their families, they could not refuse to go.

In a single year 8,000 of these workers left the department. Those who left last year received from private concerns and other institutions an average increase in salary of more than 50 per cent.; and there are instances of increases running as high as 500 per cent. If the men and women in the department were not efficient private industry would not be offering them such increases in salary. Those remaining are as efficient as those who have gone, and many of them have declined just as tempting offers. They have said in spite of low salaries and high living costs they are going to stay where they render the greatest service to the nation.

SCIENTIFIC LEGISLATION

The *Journal* of the Washington Academy of Sciences notes the following matters of scientific interest in the third session of the Sixty-sixth Congress convened on December 6, 1920:

Under a special rule adopted on December 14, the joint resolution (S.J. 191) to create a

joint commission on reorganization of the administrative branch of the Federal Government was brought up for two hours' debate on that date and passed by the House, having already passed the Senate on May 10. The bill became Public Resolution No. 54 on December 30 without executive approval. The resolution requires the committee to make a report in December, 1922. Mr. Smoot announced in February that the committee would do the work personally and would not turn it over to the Bureau of Efficiency or any other governmental agency. Considerable shifting and rearrangement of the scientific bureaus has been predicted as a probable outcome of the reorganization movement.

The House Committee on Patents recommended on December 10 that the Nolan Patent Office bill (H.R. 11984) be sent to conference, but unanimous consent for such reference was refused in the House. Later, on December 14, the bill was sent to conference, and hearings were reopened by the conference committee in January. Section 9 of the bill, providing for the issuance of patents to Federal employees, continued to meet with opposition from commercial and industrial interests, but was retained in the bill. The House agreed to the conference report on February 16. Opposition developed in the Senate, and the bill did not reach final action before the end of the session on March 4.

The bill for Federal supervision of the nitrate plants (S. 3390), including provision for research on the fixation of nitrogen, was made the unfinished business in the Senate on December 15. After several debates and the adoption of a number of amendments, the bill passed the Senate on January 14. The House took no final action.

The American Society of Zoologists, at its annual meeting on December 28–30, 1920, passed resolutions protesting against the passage of that part of H.R. 7785 (the scientific apparatus tariff bill) which abolishes the "duty-free privilege" to educational institutions. Occasional protests against this feature of the bill have been discussed in current scientific and technical periodicals. This feature of the bill was brought up in a hearing on the Fordney emergency tariff bill before the House Committee on Ways and Means on February 14, and the sentiment of the committee seemed to be strongly in favor of eliminating the duty-free privilege on chemical glassware, chemical porcelain and apparatus. The Fordney bill passed both houses, but was vetoed by the president.

As for the special bill for a tariff on scientific supplies (H.R. 7785), although it had passed the House as long ago as August 2, 1919, the Senate took no final action and it lapsed with the adjournment on March 4.

A bill "to fix the metric system of weights and measures as the single standard for weights and measures" was introduced in the House by Mr. Britten on December 29 (H.R. 15420), and in the Senate by Mr. Frelinghuysen (by request) on December 18 (S. 4675). The bills are said to have been "fathered" by the World Trade Club of San Francisco. They were referred to the respective weights and measures committees and no further action was taken.

The Smith-Towner bill to create a Department of Education (S. 1017 and H.R. 7) after lying dormant through nearly the entire life of the Congress, was reported in the House on January 17 and in Senate on March 1, but progressed no further.

A step toward the erection of the proposed building for the National Academy of Sciences was taken in the introduction of S. 4645, "to authorize the Commissioners of the District of Columbia to close upper Water Street between 21st and 22d Streets, N.W." The bill pased the Senate on February 24, but advanced no further.

With the adjournment of the Sixty-sixth Congress at noon on March 4, various other bills and resolutions which are of interest to scientific men either perished in committees or at an intermediate stage of progress.

LECTURES BEFORE THE SIOUX CITY ACADEMY

The Academy of Science and Letters of Sioux City, Iowa, arranged for the present year a weekly lecture program as follows:

"The culture areas of the early Iowa Indian," Professor Charles R. Keyes, Cornell College.

"The origin of the prairies." Professor B. Shimek, Department of Botany, University of Iowa.

"From Iowa to New Zealand and back," Rev. L. M. Dorreen, Sioux City.

"How we Americans select our President," Professor L. E. Aylesworth, Department of Political Science, University of Nebraska.

"Problems of Jackson's administration," Professor H. W. Caldwell, Department of History, University of Nebraska.

"Transmutation of elements," Professor M. E. Graber, Department of Physics, Morningside College.

"The last stand of the Sioux," Hon. Doane Robinson, State Historian, Pierre, S. D.

"Unfinished Iowa," Professor O. E. Klingaman, director of Extension Department, University of Iowa.

"History of American art," Professor Paul H. Grummann, Dean of the Department of Fine Arts, University of Nebraska.

"The history of the Missouri," Professor Freeman Ward, Department of Geology, University of South Dakota.

"Periods of architecture in America," W. L. Steele, Architect, Sioux City.

"Becoming acquainted with the suns," Professor G. D. Swezey, Department of Astronomy, University of Nebraska.

"Survey of prehistoric man," Professor H. G. Campbell, Department of Philosophy, Morningside College.

"Our raw material," Professor Hattie Plum Williams, Department of Sociology, University of Nebraska.

"Our native landscape of Mid-America," Mr. Jens Jensen, Ravinia, Ill.

"Our local bird life," Professor C. S. Thoms, Department of Sociology, University of South Dakota.

"Remaking the face of Iowa," Professor R. B. Wylie, Department of Botany, University of Iowa.

COOPERATION OF NATIONAL HEALTH AGENCIES

Coordination of the work of voluntary national health agencies has been effected on May 1, a number of these organizations will take possession of two floors of the Penn Terminal Building, in Seventh Avenue at Thirty-first Street, New York City. The National Health Council was formed last fall by organizations, each of which will retain full autonomy. The new arrangement is in no sense a merger, but an effort to bring the organizations together for economy in overhead expenses and for cooperation in health programs. In addition to its work in coordinating the efforts of private health agencies, the council will maintain an inter-organization information service; a health legislative bureau, which will keep track of national and State health legislation and keep council members fully informed on it, and a statistical bureau. It also expects to aid in the development of health educational material and will foster periodic joint conferences among members of the various participating organizations.

On the fifteenth floor of the Penn Terminal Building will be the offices of the American Social Hygiene Association, the National Committee for Mental Hygiene, the National Organization for Public Health Nursing cooperating with the American Nurses' Association and the League for Nursing Education, and the National Tuberculosis Association.

On the sixteenth floor there will be offices for the American Public Health Association, formerly in Boston; the Bureau of Social Hygiene, the Child Health Organization of America, probably the liaison office of the United States Public Health Service, the National Health Council, with the Common Service Committee; the Maternity Center Association, the New York Diet Kitchen Association, the New York Community Service, and probably the American Society for the Control of Cancer.

The Federal Board of Vocational Education already has its New York offices in the Penn Terminal Building, on the fourteenth floor.

Officers of the National Health Council, which not only maintains its offices in New York, but has a national headquarters office in Washington, are: Chairman, Dr. Livingston Farrand; vice-chairman, Dr. Lee K.

Frankel; secretary, Dr. C. St. Clair Drake; acting treasurer, Dr. William F. Snow; acting executive officer, Dr. Donald B. Armstrong.

THE AMERICAN METEOROLOGICAL SOCIETY

The fifth meeting of the American Meteorological Society will be held on April 20 and 21 at the Central Office of the Weather Bureau, Washington, D. C. Including the six papers to be presented at the meeting of Section (c), meteorology, of the American Geophysical Union on April 19, the program as published in the April *Bulletin* of the society contains 27 titles of varied interest. Abstracts of all these papers and of such discussions as may follow them will be published in the *Bulletin of the American Meteorological Society;* and most of the papers themselves will probably be published in the *Monthly Weather Review.*

The proceedings of the first annual meeting of the society at Chicago on December 29, 1920, were published in the January issue of the *Bulletin.* A motion to increase the annual dues from $1 to $2 was lost because of the desire not to curtail the membership merely for money, which could be raised in other ways. A resolution favoring the Weather Bureau's estimates for increased appropriations was passed, but it had no effect in persuading Congress to recognize the dire straits of the bureau with its present program of service. Rather full information about the 32 papers on the scientific portion of the program appeared in the February and March *Bulletins.* Many of these papers have since been published in the *Review.*

Charles F. Brooks,
Secretary

Washington, D. C.

THE EDINBURGH MEETING OF THE BRITISH ASSOCIATION

From *Nature* we learn that for the meeting of the British Association, which will be held in Edinburgh on September 7-14 next, the following presidents of Sections have been appointed: Section A (Mathematics and Physics), Professor O. W. Richardson; B (Chemistry), Dr. M. O. Forster; C (Geology), Dr. J. S. Flett; D (Zoology), Mr. E. S. Goodrich; E (Geography) Dr. D. G. Hogarth; F (Economics), Mr. W. L. Hichens; G (Engineering), Professor A. H. Gibson; H (Anthropology), Sir J. Frazer; I (Physiology), Sir W. Morley Fletcher; J (Psychology), Professor C. Lloyd Morgan; K (Botany), Dr. D. H. Scott; L (Education), Sir W. H. Hadow; and M (Agriculture), Mr. C. S. Orwin. Sir Richard Gregory has been appointed president of the Conference of Delegates of Corresponding Societies. Among the subjects of general interest which are being arranged for discussion at joint sectional meetings are: The Age of the Earth, Biochemistry, Vocational Training and Tests, The Relation of Genetics to Agriculture, The Proposed Mid-Scotland Canal, and The Origin of the Scottish People. The president of the association, Sir Edward Thrope, will deliver his address at the inaugural meeting on Wednesday evening, September 7, and discourses will be given at general evening meetings by Professor C. E. Inglis on The Evolution of Cantilever Bridge Construction, involving a comparison between the Forth and Quebec bridges, and by Professor W. A. Herdman, the present president, on Edinburgh and Oceanography. Measures are being taken towards a more effective coordination of the daily programs in order to avoid the clashing of subjects of kindred interest.

SCIENTIFIC NOTES AND NEWS

Prince Albert of Monaco, sailed on April 9 for New York on his way to Washington to receive the Alexander Agassiz gold medal awarded by the National Academy of Sciences to him in recognition of his promotion of oceanographic research. He will give an address before the academy on the evening of April 25.

Professor Albert Einstein will be the guest of Princeton University from May 9 to 15, and will give five lectures on the theory of relativity. Professor Einstein and Dr. Weiz-

mann have been given the freedom of the City of New York.

VILHJALMUR STEFANSSON, on motion of the prime minister of Canada, has recently received the thanks of the Canadian government for his public services during the years 1906–1919. The action was based partly on his work in science and in geographic discovery, and partly on his having called to the attention of the country great economic resources in the north that had been previously unknown or undervalued. "He has turned men's minds towards the north country as a possible source of food supply and home for colonists, and his work and advice have proved the greatest incentive in promoting public and private development of our northern resources." For his geographic work, Mr. Stefansson had already received several gold medals from learned societies in America and Europe.

THE Boyle medal of the Royal Dublin Society has been awarded to Dr. George H. Pethybridge, botanist of the department of agriculture, Dublin.

SIR WILLIAM J. POPE has been elected an honorary member of the French Chemical Society.

DR. H. K. ANDERSON, master of Gonville and Caius College, Cambridge; Professor W. M. Bayliss, professor of general physiology, University College, London; and Sir William H. Bragg, Quain professor of physics, University of London, have been elected members of the Athenæum Club, London, for eminence in science.

DR. SOLON SHEDD, professor of geology at the State College of Washington, Pullman, has been appointed state geologist. Dr. Shedd will retain his position as professor of geology at the State College.

MR. C. R. DELONG has been appointed chief of the chemical division of the U. S. Tariff Commission, succeeding Dr. Grinnell Jones, who has returned to Harvard University, but retains a connection with the commission in an advisory capacity. The other members of the chemical staff are: S. D. Kirkpatrick, W. N. Watson and A. B. Willis.

THE annual general meeting of the Chemical Society was held on March 17, when, as we learn from *Nature*, Sir David J. Dobbie, the retiring president, delivered his address. The following officers and members of council were declared elected: *President:* Sir James Walker. *Vice-presidents who have filled the office of president:* Professor H. E. Armstrong, Sir James J. Dobbie, Professor W. H. Perkin, Sir William J. Pope, Dr. Alexander Scott and Sir William A. Tilden. *Other Vice-presidents:* Professor F. G. Hopkins, Professor F. S. Kipping and Professor J. F. Thorpe. *Ordinary Members of Council:* Professor J. S. S. Brame, Dr. C. H. Desch, Mr. E. V. Evans, Mr. H. B. Hartley, Dr. T. S. Patterson, Dr. T. Slater Price, Mr. W. Rintoul, Dr. R. Robinson and Dr. N. V. Sidgwick.

DR. WALTER E. COLLINGE, of St. Andrews University, has been appointed keeper of the York Museum.

DR. COLIN G. FINK, organizer and for the past four years director of the Research Laboratories of the Chile Exploration Company has resigned his post. Formerly Dr. Fink was in charge of research at the Edison Lamp Works.

MR. W. M. SMART, Trinity College, chief assistant at the Cambridge Observatory, has been appointed to the John Couch Adams astronomership, recently founded under a bequest by the late Mrs. Adams.

COLLIER COBB, professor of geology at the University of North Carolina, Chapel Hill, is on a year's leave of absence under the Kenan Traveling Fund. He is studying shore-lines and shore-line processes in Japan.

PROFESSOR HERBERT OSBORN, of the Ohio State University, has recently returned from a two months' stay in Florida, during which he collected entomological material at different points in the state with cooperation of the State Plant Board of Florida.

DR. FRANK APP, of Rutgers College, has been given a year's leave of absence to become sec-

retary of the New Jersey State Council of County Boards of Agriculture.

Friends of Professor Chandler presented in 1910 to Columbia University a sum of money which constitutes the Charles Frederick Chandler Foundation. The income from this fund is used to provide a lecture by an eminent chemist and to provide a medal to be presented to the lecturer in further recognition of his achievements in science. Previous lecturers on this foundation were L. H. Baekeland, W. F. Hillebrand and W. R. Whitney. The lecturer this year will be Frederick Gowland Hopkins, professor of biological chemistry, Cambridge University, England. The Chandler Medal will be presented to Dr. Hopkins in order to recognize his pioneer and very valuable work in the study of food accessories, such as vitamines. Professor Hopkins' subjects will be "Newer Aspects of the Nutrition Problem." His lecture will be in Havemeyer Hall, Columbia University, on the evening of April 18.

Dr. A. J. Lotka, who is working as a guest in the department of biometry and vital statistics of the school of hygiene and public health of John Hopkins University, gave in April a series of four lectures on "The dynamics of evolution and the foundations of physical biology."

Sir Walter Fletcher, secretary of the Medical Research Committee of Great Britain, will deliver the Tenth Harvey Society Lecture at the New York Academy of Medicine, Saturday evening, April 16. His subject will be: "The state's relation to medical activities in Great Britain."

Dr. Herbert Haviland Field, who in 1895 founded at Zurich the Concilium Bibliographicum, died suddenly of heart disease on April 5, at Zurich, where he had lived. He was born in Brooklyn in 1868, graduated from Harvard in 1888.

Dr. Thomas Benjamin Doolittle, of Branford, Conn., said to be the originator of the first telephone switchboard and associated in the organization of the original Bell Telephone Compnay in Boston, died on April 4, at the age of eighty-two years. Dr. Doolittle in 1898 received the Edward Longstreth medal from the Franklin Institute of Philadelphia for developing the process of producing hand-drawing copper wire.

Dr. Alfred Doolittle, professor of mathematics and instructor in astronomy at the Catholic University since 1898, died on February 23.

We learn from the *Journal* of the Washington Academy of Sciences that Mr. Frederic Perkins Dewey, assayer of the Bureau of Mines of the Treasury Department, died on February 10, in his sixty-sixth year. Mr. Dewey after graduation from Yale University became instructor in chemistry at Lafayette College. From 1881 to 1889 he was connected with the U. S. Government, first as chemist with the Tenth Census, then as mineralogist with the Geological Survey, then as curator in the National Museum. After 24 years in chemical and metallurgical patent practise he became assayer of the Mint in 1903.

Dr. E. Béraneck, professor of biology at the University of Neuchâtel, has died at the age of sixty-one years.

The death is also announced of Dr. León Becerra, chief health officer of Guayaquil, Ecuador, a member of the Rockefeller commission studying the yellow fever situation.

A course of four public lectures on the history of plant delineation was given during March in the botany department of University College, London. The first two, on the art of the ancient empires and the dark and middle ages, was delivered by Dr. Charles Singer, and the other two, bringing the subject down to recent times, by Dr. Agnes Arber.

The United States Civil Service Commission announces an examination for the position of scientific assistant in the U. S. Bureau of Fisheries at $1,200 (plus $20 a month), to be held on April 27. Applicants will be rated chiefly upon zoology in its relation to the fisheries, and general biology.

A regular meeting of the American Physical Society will be held in Washington, at

the Bureau of Standards, on Saturday, April 23. If the length of the program requires it, there will also be sessions on Friday, April 22. Other meetings for the current season are as follows: August 4, 5, Pacific Coast Section at Berkeley; November 25, 26, Chicago, December 27–31, Toronto, annual meeting.

Penikese Island, Buzzards Bay, was abandoned as a leper colony on March 10. The thirteen lepers on the island with three from Bridgeport, Conn., and two from Richmond, Va., were transferred to the federal leprosarium recently established at Carville, La.

UNIVERSITY AND EDUCATIONAL NEWS

A building plan for its medical school in Chicago has been adopted by the University of Illinois in cooperation with the state department of public welfare. What was formerly a ball park, just south of the Cook County Hospital, Chicago, is to become the campus. The buildings now under construction are a clinical institute, a new building for the Illinois Charitable Eye and Ear Infirmary, a psychiatric institute and an institute for crippled children. Later, the clinical institute and the orthopedic institute will be enlarged and additional buildings will be erected for infectious diseases, venereal diseases, a research institute, a library, class rooms, research laboratories and a dental institute. The Elizabethan style of architecture has been selected.

The Senate of the University of London has adopted a resolution to continue the physiological laboratory at South Kensington until the end of 1923.

Dr. L. Emmett Holt, Carpentier professor of the diseases of children at the College of Physicians and Surgeons, Columbia University, has resigned this chair and the administrative conduct of the department, and has been appointed chemical professor of the diseases of children.

At the Harvard Medical School Dr. Philip Drinker, of the Buffalo Foundry and Machine Co. and Dr. Douglas A. Thom have become instructors of applied physiology and psychiatry, respectively. Dr. Frederick L. Wells, director of the Psychological Department of the Psychopathic Hospital, Boston, has been given an appointment as instructor in experimental psychopathology.

Mr. F. C. Thompson, Sorby research fellow of the Royal Society, has been appointed to the chair of metallurgy in the University of Manchester.

DISCUSSION AND CORRESPONDENCE

POSITIVE RAY ANALYSIS OF LITHIUM

Applying the method of positive ray analysis previously used[1] to the element lithium, I have recently found that it is composed of two isotopes. With positive ions from heated lithium salts G. P. Thomson and F. W. Aston have also obtained two components.[2] In my experiments the metal itself was evaporated in a small iron capsule, heated electrically. The two rays corresponding to atomic weights 6 and 7 were widely separated and appeared simultaneously as the heating current was increased. The absolute atomic weights could be checked by comparison with hydrogen atoms which were driven off from the metal; the setting on the maxima of the two components was so accurate that assuming a molecular weight of exactly 6 for the lighter, the heavier atomic weight was 7.00 within 2 units in the second decimal place, thus excluding the possibility of a simple element with the chemical atomic weight 6.94. Any further isotopes at 4, 5, 8 or 9 must be less than 2 per cent. of that at 7.

It was also observed that the proportion of the two components varies with the experimental conditions. The lighter at 6 is sometimes one quarter as strong as that at 7, but under other conditions of heating and pressure, it appears weaker and sometimes is only one twelfth as strong. To obtain a mean atomic weight of 6.94 the lighter should be only one sixteenth as strong as the heavier,

1 Science, December 10, 1920.

2 *Nature*, February 24, 1921.

but it has always been found stronger than that. This variability is of interest as showing that there are differences in the properties of the two isotopes, and of course the effect of mass differences should be specially evident, on account of the large mass ratio 6 to 7, in the case of lithium.

A. J. Dempster
Ryerson Physical Laboratory,
University of Chicago

A REMEDY FOR MANGE IN WHITE RATS

A simple method of keeping white rats for experimental work free from mange has been successfully used for some time in this laboratory. Sore ears, noses and tails are quite common in rat colonies and are not caused by deficient rations, as is often thought, but by a parasite known as the *Notoedres alenis*.[1]

The lesions on the ear, due to the mange produced by this parasite, are very characteristic, causing the whole ear to swell and become inflamed with the outer edge of the ear fringed with a cauliflower-like incrustation. On the tail the lesions resemble those on the ear, while on the nose they frequently take the form of horn-like protuberances. These lesions can be readily differentiated from other lesions by the application of insecticides. We have found that pine oil[2] applied with a soft brush will heal affected parts very quickly. This oil has not only very healing properties, but also strong antiseptic and anesthetic properties. Because of the latter care must be exercised in its application.

Since learning of the effectiveness of this oil it is the custom in this laboratory to wash our animal cages once a week with hot water and soap and to spray the sawdust used on the floor of the cages with the oil. In this way all lice and parasites which are ordinarily troublesome pests in animal colonies are kept down to minimum. If an individual rat becomes infested with lice it can be sprayed with the oil. An atomizer is used for this purpose.

Cornelia Kennedy
Minnesota Agricultural Experiment Station

1 Private communication of Dr. B. H. Ransom, Bureau of Animal Industry, to Dr. J. E. Foster, formerly with the Mayo Clinic.

2 The pine oil used for the experiments was furnished by the Newport Company of Pensacola, Fla., through the courtesy of R. C. Palmer, chief chemist.

IMPOSSIBLE (?) STORIES

Dr. Campbell's astonishment at the actual occurrence of the Mark Twain incident (March 4) "reminds me." I had looked upon the Irishman's astronomy as related by DeMorgan[1] as a good "manufactured" story.

Long life to the moon for a dear noble cratur
Which serves for lamplight all night in the dark,
While the sun only shines in the day which by natur
Wants no light at all as ye all may remark.

I was astonished to hear Dr. W. C. Farabee, of the University Museum, relate that in his South American expedition he found the Shipibos Indians worshipping the moon and that upon inquiry they gave the same reason as the Irishman.

Samuel G. Barton
University of Pennsylvania

1 "Budget of Paradoxes," p. 242, 2d ed.

QUOTATIONS

INTERNATIONAL SCIENTIFIC ORGANIZATION

There is much to be said in favor of "teamwork," the concentration of many experts on a single problem or on one aspect of a problem. Some inquiries are so vast in scale that progress on any other lines can not be expected.

The modern telescope has made known the existence of myriads of stars beyond those visible to the unassisted eye. The counting and classification of this multitude can be achieved only by the concerted patience of many men in many countries, and may yet form the basis of some new conception of the order of the universe. Meteorology and geodesy, the attempt to plot the shape of our earth from a number of long base lines, must be international. The determination of standards is of little use unless it lead to universally agreed methods and results. The development and control of fisheries, the ap-

pointment of close times, and the protection of breeding areas require cooperation.

Many minor problems, such as the study of variations in human anatomy, can be advanced most quickly if all the opportunities in different countries are employed simultaneously on a selected object. Such examples could be multiplied indefinitely. International team-work is required sometimes merely as the quickest means of attaining the object, sometimes because no other method is possible, sometimes because common practical interests are involved.

Before the war international scientific cooperation was obtained in several ways. As many as 40 to 50 international bodies had come into existence in response to the need. Some were sustained by formal conventions arrived at through the usual diplomatic channels; others were due to the efforts of individual scientific societies or interests; many were the informal result of personal effort directed to a common purpose. All these were rudely interrupted by the clash of arms, and much water will have to pass under the bridges before the healing process has been completed. But it has already begun.

Through the booksellers work published during the war is creeping across the frontiers; the impersonal exchange of publications has been resumed between many of the learned societies; there has even been a little furtive correspondence between individuals. Science could not wait. The theory of Einstein, the German Jew, was put to the test by British astronomers; physiologists and doctors here and in Germany had to use the same methods of research in struggling against the same problems of altered nutrition and of damaged men, and could not let their service of humanity be restricted by a local patriotism. Had it been allowed to take its natural course, this cold, almost stealthy redintegration would have offended no one and would, indeed, have assisted towards the open internationalism which we must all hope for our sons or sons' sons, although we can not even wish it for ourselves.

But there were the formal conventions. On these descended a little group of diplomatists of science, almost as aloof from the real feelings of those whom they claimed to represent as the big men of the Peace Conferences. They held a conference in London in October, 1918, when every one except themselves knew that the war was almost over. They resolved, good people, that it "was desirable that the nations at war with the Central Powers should withdraw from the existing conventions relating to International Scientific Associations in accordance with the statutes or regulations of such conventions respectively, as soon as circumstances should permit," and that "new associations, deemed to be useful to the progress of science and its applications, be established without delay by the nations at war with the Central Powers with the eventual cooperation of neutral nations."

Then came the armistice and then, after an interval so long that impersonal relations with our former enemies had begun to be resumed, came the Peace Treaty. By that the Germans undertook to withdraw from most of the scientific conventions. Nevertheless, so far as the Allies and neutrals were concerned, these remained in existence. The same group of amateur diplomatists called a conference at Brussels larger in numbers but equally unrepresentative in character. This conference proceeded to destroy the last remnants of existing international cooperation. First they withdrew themselves from all the conventions; next they excluded all the Central Powers; thirdly they excluded all the neutrals. Having thus created chaos, they proceeded to the elaboration of a scheme of superorganization almost pathetic in its sterile incompetence.

The basis of the wonderful edifice is an International Research Council. This is to be the supreme body in all the affairs of science, to coordinate international efforts, to initiate new international unions, to direct international activity and to negotiate with governments. Its constitution is to remain in force for ten years and all subordinate

unions or associations are to comply with its statutes. Of these the vital clause is that membership is to be limited at first to what were the Allied countries during the war but that countries then neutral may be admitted if they obtain a favorable majority of not less than three-quarters of the countries already in the Union. It appears to be the case that former enemy countries if they choose to plead for admission and can obtain a three-quarters majority are also eligible, but there is dispute as to the interpretation of the phrases. In any event the scheme perpetuates for ten years the division of the nations into the groups of war with the addition that former neutrals are asked to desert their neutrality and join the Allied scientific combine.

The legal domicile of the new supreme body is to be at Brussels where the funds are to be kept, and triennial general assemblies are to be held. An executive committee consisting of five members (a "big five") is to direct the affairs of the Research Council between the meetings of the Assembly. All the branches of science are invited to form international unions with their statutes in agreement with those of the Research Council.

The organization is actually in existence and several of the subordinate international unions have been formed. But how far these have any real significance or vitality it is more difficult to say. The statutes laid down that a country could join the International Research Council or any Union connected with it through its principal academy, its national research council, some other national institution or association of institutions, or through its government.

It is therefore clearly within the power of bodies without a direct mandate from scientific men as a whole to make their countries formal participants. British biologists, for example, have formally refused to join an International Biological Union on the double ground that the complex organization will hinder rather than help cooperation, and that the constitution perpetuates international divisions which should be left to time to heal. But the promotors of the scheme are making efforts to create a "National Council" which could then enter the new edifice by a back door. No clear statement has been published as to the action of other countries, but evidence accumulates as to the absence of real support for the scheme of super-organization.—*The London Times.*

The issue of the *Times* published on March 8 contains an article headed "The Progress of Science; Revolt against Super-Organization." A few words of comment are necessary, though the task is disagreeable owing to the general tenor of the article, which in parts is frankly abusive and in others misleading. Its chief invective is directed against the International Research Council. This, according to the author, is to be "the supreme body in all the affairs of science," and he follows up this product of his imagination by enumerating in the same sentence the avowed objects of the International Research Council, placing a pure invention of his own in juxtaposition to the actual functions of the body concerned so as to leave the impression that both have equal authority.

The International Research Council was founded in the first instance through the action of the Royal Society and the Academies of Paris, Italy, Brussels and Washington. Its object was to reorganize international work which had come to a standstill through the war, and to extend it where found desirable. The question as to the time at which former enemy countries should be admitted is a matter for argument, and it may be the policy of the *Times* to urge their immediate inclusion in the interests of the general peace of the world. Recent incidents at a meeting in Paris at which a German professor took part do not confirm this view, but the question has had nothing to do with the purpose which the writer pretends to discuss. It should not be forgotten, however, that a friendly personal intercourse is an essential condition of the success of international conferences. This is recognized by the countries neutral during the war, which have nearly

all accepted the invitation of the International Research Council to take part in this common enterprise.

The International Research Council has initiated the formation of unions for the conduct of scientific work. In the subjects of astronomy, geodesy and geophysics, and chemistry such unions are actually at work, and two others have been formed. Once an international union is established it becomes autonomous, and conducts its work without interference from the International Research Council except in a few matters in which a common policy is desirable.

Every one knows that the decisions of an international conference are only advisory, and have no binding force on the separate countries. Representatives taking part in the conference report to the home authorities concerned, who act as they think fit, accepting, no doubt, in general such recommendations as have secured practical unanimity. At a recent meeting in Brussels certain countries desired to initiate the formation of an International Union of Biology, and their representatives tentatively drew up some statutes. These were submitted to a competent body in this country, which reported unfavorably, and there the matter ends so far as Great Britain is concerned. This does not, of course, prevent France, Italy, the United States, and other countries from forming a Union of Biology if they wish. I fail to understand where the grievance of the *Times* comes in.—Arthur Schuster, General Secretary of the International Research Council, in *Nature*.

SCIENTIFIC BOOKS

THE TERRESTRIAL LIFE ASSOCIATED WITH THE COALS OF NORTHERN FRANCE

IN a large, very detailed, and well-illustrated memoir published by the French Ministry of Public Works,[1] Dr. Pierre Pruvost of the University of Lille Museum, has given us the most extensive work so far published on the fresh-water and land invertebrates of the Coal Measures of northern France, that is, of the Westphalian, the equivalent of our Pottsville and Allegheny series. The memoir is based on the "documents preserved in the museum of the University of Lille . . . which never could have been brought together without the cooperation of the mining engineers and the scientific men who are exploiting the basin of the north," and its object is so to define the faunal zones as to give to these same mining men fixed points from which they can reckon the stratigraphic position of their coals.

From the 17 species heretofore known in the fauna, the number is now increased to 116, 54 of which are new. They represent the following classes: 13 bivalves, 1 tubiculous annelid, 6 ostracods, 5 phyllopods (3 new), 3 Malacostraca, 2 Syncarida, 53 specifically determined insects (43 new), 1 eurypterid, 3 limulids, 7 spiders (3 new), 4 sharks, 6 crossopterygians (2 new), and 12 ganoids (3 new). These forms are found in 6,970 feet of Westphalian strata, divided into 5 formations and 9 members, most of which are of fresh-water origin, since it is only in the lower 2,350 feet that there is occasional evidence of the sea, this being most decided near the base.

The common fossils with limited ranges and therefore of value in correlating the various horizons are shown to be (1) the bivalves (*Carbonicola, Anthracomya, Naiadites*), (2) the phyllopods (*Estheria, Leaia*), and (3) the scales and teeth of fishes. The ostracods *Carbonia* and *Cypridina* and the annelid *Spirorbis* are all long-ranging, while the insects, even though they are of very short range—in fact, but very few forms extend through more than one zone—occur too rarely to be useful in detailed stratigraphy, other than of a local basin. It is interesting to note that the fresh-water life has in its time duration about the same zoning value as the plants, and that both classes of organic evidence lead to the making of the same general time divisions. With these results attained, the author then paral-

[1] "Introduction à l'Étude du Terrain Houiller du Nord et du Pas-de-Calais. La Faune Continentale du Terrain Houiller du Nord de la France. Mémoires pour servir à l'explication de la carte géologique détaillée de la France," pp. 584 (quarto), 29 pls., 51 text figs., Paris, 1919.

lels the different coal beds of northern France with those of Belgium and England.

The greater part of the volume is taken up with the insects (pp. 93–321), and the author confirms Handlirsch's conclusion that during Westphalian time hexapods were large, in fact, that as a rule they were "giants." Pruvost thinks that the Westphalian insects were not all carnivorous, but that some may have fed on the pollen, etc., of plants like the cordaites and cycadophytes; in other words, that the rise of the insect world was largely conditioned by the development of inflorescence among plants.

Insect impressions, to be preserved in the rocks, must be entombed in the very finest of sediments. The author states that they are found only in shales, in association with delicate plant remains, and with those of animals as well. The very best ones, of rare occurrence, have, however, suffered no appreciable transport or maceration, but were buried quickly along with the most fragile plants in the softest of muds; while the majority of the specimens found commonly in the "insect beds" have undergone more or less long periods of floating, and consequent maceration and dissociation. The floated specimens occur at times with stronger plant fragments and the remains of animals, all in varying degrees of decomposition.

Pruvost breaks up Handlirsch's order Protorthoptera, and puts the majority of his families in a new suborder, the Archiblattids (3 species described), which are present as early as the base of the Westphalian. These are "the simplest and oldest of Protoblattoidea" and they may have had their origin in the Paleodictyoptera, the original source-stock of all insects. Two other suborders of Protoblattids are erected, Mimoblattids (for American forms) and Archimantids (1 described). The author remarks on "the homogeneity and antiquity of the blattid phylum," describing 43 forms, and on its early separation from the rest of the orthopterids. Of Paleodictyopterids he describes but 3 forms. He believes that the greatest evolution of Paleozoic insects took place during the Westphalian, and states that at the top of the Lower Carboniferous (Dinantian or Mississippian) but one order is known; early in the Westphalian three orders are "scarcely outlined"; and at the end of the Westphalian "almost all the Paleozoic phyla are fully established."

The evolution of insects was especially rapid at the base of the Westphalian (Flines member), again at the base of the upper part of the same series (Ernestine), and at the top of the Westphalian in the Edouard member. And this threefold acceleration in insect evolution is in harmony with the floral enrichment.

We must add here that the supposed insects found in the Horton formation (early Mississippian) of New Brunswick, Canada, and mentioned in the table opposite page 293, have been shown to Professor H. F. Wickham and Dr. David White, with the result that both paleontologist and paleobotanist agree that they are not insects but the carbonized fragments of woody plants.

To the young author, a favorite student of Professor Barrois under whose direction are being carried out a series of studies designed to apply the "paleontologic method" to the problems of the coal basin of northern France, are extended our congratulations on his great achievement.

Charles Schuchert

SPECIAL ARTICLES

THE RELATIVITY SHIFT OF SPECTRUM LINES

Three experimental tests of Einstein's Relativity Theory of Gravitation have been proposed. Two seem to have been verified experimentally. The third, the predicted shift of solar spectrum lines, is still very much in dispute. Evershed and Royds,[1] and Schwarzschild[2] obtained very discordant results. St. John,[3] with very fine apparatus, also obtained very discordant results with however a zero effect, on the average. Grebe and Bachem[4] at first obtained discordant results, but a more careful analysis of their

[1] Bulletin 39, Kodaikanal Observatory.

[2] *Sitzungsberichte*, Berlin Akad., p. 1201, 1914.

[3] *Astro. Jour.*, 46, 249, 1917.

[4] *Verh. d. D. Phys. Ges.*, 21, 454, 1919.

data[5, 6, 7] yielded more consistent results and results in agreement with theory. Using the lines near the head of the CN 3883 band, the shift of solar wave-lengths, compared to terrestrial, should be 0.0082 Å to the red, equivalent to the Doppler effect of a descending current on the sun of 0.634 km./sec.

It appears to the author that a spectral line must rigidly fulfill three conditions, in order to be suitable for use in this work. (1) It must show no pressure shift, pole-effect, or other variation of frequency with physical condition of the source (excluding gravitational effects), (2) it must be a single, sharp, symmetrical line, (3) it must, in the solar spectrum, be quite free from other "foreign" lines.

Band lines are used because they seem to fulfill condition (1). In the early work proper attention was not paid to condition (3). Grebe and Bachem,[6] by obtaining microphotometric curves, have attempted to rigidly satisfy condition (3), and in doing so have had to discard all but eleven of the 36 lines formerly measured by them. But *no* investigators have made an attempt to rigorously satisfy condition (2). Now the author, in arriving at a new formula for band series,[8] obtained very fine spectrograms of the 3883 band, and made an extended investigation of its structure, supplementing the work of Uhler and Patterson.[9] There are a number of different series in this band (twenty in all, commonly classified as ten series of doublets), but without exception the individual members of the various twenty series are *sharp, symmetrical* lines. This is a noteworthy characteristic of most band series, differentiating them from line series, the members of which are *all* complex, according to the Bohr-Sommerfeld theory. Moreover these latter are quite susceptible to changing electrical conditions.

But the ten doublet series of the 3883 band have different spacing and so are continually crossing, resulting very frequently in an apparent *broad, unsymmetrical* line, even with the best resolving power at our disposal. But this *complex* is really only the superposition, or partial superposition of two or more *sharp, symmetrical* lines. It is self-evident that the *apparent* center of gravity of such a complex depends on the length of exposure, etc., while the position of the "peak" of a micro-photometric curve depends on the relative intensity and position of the component members of the complex. It is known that the relative intensity of certain series in the 3883 band changes with physical conditions, and there is evidence that their relative intensity in the sun is *different* from that in the ordinary carbon arc. Hence any apparent "line" which is really a *complex* is entirely unsuitable for the detection and measurement of so small a shift as that predicted by Einstein. This is especially true as the solar lines are in absorption, while the arc lines are in emission.

The author, in his analysis, has identified many series lines, not previously identified, and by obtaining accurate formulæ for the stronger series, has been able to compute "theoretical" positions for all lines of these series, including those entering into complexes. In all cases tested, the actual appearance of the complex was in agreement with the theoretical structure thus built up. Also, many complexes have been recognized which may not previously have been suspected as such, and the presence of several extraneous lines in the normal arc spectrum (carbon lines, but not band lines) has been detected. Thus material is at hand for a rigid investigation of the eleven lines finally used by Grebe and Bachem. The details of this work will be published elsewhere. Only the results are given here.

Of the eleven lines only *two* (λ 3873.504 and λ 3858.822, on the Rowland system) fully satisfy condition (2). Even this is not strictly correct, for the two lines are unresolved doublets, the 31st and 49th member, respectively, of the A_1 series. But the two

[5] *Zeit. f. Phys.*, 1, 51, 1920.

[6] *Zeit. f. Phys.*, 2, 415, 1920.

[7] *Phys. Zeit.*, 21, 662, 1920.

[8] *Astro. Jour.*, 46, 85, 1917; *Phys. Rev.*, 11, 136, 1918; 13, 360, 1919.

[9] *Astro. Jour.*, 42, 434, 1915.

components of the doublet (in the case of the hundred or so members which *can* be resolved) are of exactly equal intensity, and therefore it seems safe to assume that the unresolved doublets are at least symmetrical, and to use them. For 3873.504, Grebe and Bachem obtained a shift of 0.58 km. (average of five consistent determinations from different plates), and Schwarzschild 0.45 km. (average of four consistent plates). No other investigators have used this line. For 3858.822, Grebe and Bachem obtained 0.42 km. (average of six consistent determinations), St. John 0.40 (average of four different methods, of which only the first two are wholly independent and so entitled to the most weight, these two, *a* and *b*, yielding 0.46 km.), Schwarzschild 0.39 km. (average of four readings—three consistent).

Using the 0.46 km. value of St. John, these five determinations for the two lines average 0.46 km./sec. In all cases this is the shift between lines radiated by the center of the sun, and by the arc. But St. John (*loc. cit.*) and Adams have both obtained reliable evidence that at the center of the sun there is a rising current of about 0.12 km./sec., compared to the rim.[10] This tends to mask the Einstein effect. The true value of this effect, as experimentally determined, is then $0.46 + 0.12 = 0.58$ km./sec., compared to the theoretical 0.634. While the data are far too meager to draw any final conclusions, it is worthy of notice that the results of *all* observers are truly consistent on *really* good lines. The great discrepancy between St. John's and Grebe and Bachem's general averages has been the puzzling factor, thus far. The author believes that he has a partial explanation for this, and will present it in a later paper, together with a list of lines which are suitable for use, as far as condition (2) is concerned.

It might be added that, for the nine lines quoted by Grebe and Bachem[5, 6] (λ 3858.822 and λ 3851.427 being accidentally omitted), the agreement among different observers is worse than indicated, due to Grebe and Bachem's consistent misquoting of St. John's results, as well as other errors. The correct averages are: G. and B. 0.57, Schwarzschild 0.63, St. John 0.17 (or 0.26 using methods *a* and *b* only), Evershed and Royds 0.67. General weighted average 0.50, or 0.52, using 0.26 for St. John.

If all eleven lines are used, the averages become: G. and B. 0.52 (eleven lines), Schwarzschild 0.57 (nine lines), St. John 0.22 (eight lines, or 0.30, two good methods only), Evershed and Royds 0.67 (two lines). Average (weighted according to the number of lines), 0.46, or 0.48, using 0.30 for St. John. To all these values should be added 0.12 km. to obtain the true rim—arc value.

It should also be added that, in the author's opinion, St. John's method (*c*), and Grebe and Bachem's recent calculation[7] of 100 CN lines add comparatively little weight to the argument, as they involve the use of Rowland's standards. Since Rowland used both terrestrial and solar wave-lengths, in obtaining his table of standard lines, the Einstein shift (if real) is hopelessly involved in the measurements and can not be definitely extricated by any such method as that recently used by Grebe and Bachem.

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[10] Schwarzschild's results indicate a falling current, *not* a rising, as quoted by Grebe and Bachem, but are too discordant to have any value. St. John's are very reliable.

A NEW HIGH TEMPERATURE RECORD FOR GROWTH

A RECORD of growth of young joints of a prickly pear (*Opuntia*) at 50° C. and 51.5° C., and of the active elongation of etiolated stems of the same plant growing at 49° C. was published in 1917. Previously to that time Dr. J. M. McGee had found that the mature joints of the same *Opuntia* might reach temperatures of 55° C. in the open without damage, which was a record for endurance of the higher plants in air.

In the repetition of the growth measurements at the Desert Laboratory late in March, 1921, young joints which might reach tem-

peratures of 49° C. in the sun in an unventilated glass house were heated further by the use of electric grills. Temperatures were taken by mercurial thermometers with bulbs of the clinical type thrust into joints within a few centimeters of the one being measured, but which had equivalent exposure.[1]

The elongation of the joints during this youngest stage is directed by the temperature, and the retardations due to maximum night transpiration and acidity which come in later are not yet manifest. The rate of elongation therefore is greatest in midday and early afternoon. Such a joint showing a temperature by the inserted thermometer of 43.5° C. was subjected to the additional heating of the electric grill at 1:30 P.M. At 2 P.M. the temperature passed 51° C. with growth still in progress, the rate but little lessened from that of 1 mm. in 24 hours which it was showing at the beginning of the test. The temperature was now raised slowly until 3 P.M. the joint stood at 51.5° C., the maximum at which growth had ever been observed in any seed plant. At 3:10 a temperature of 54.5° C. was reached and five minutes later the readings were 55.5° C. The joint was kept for an hour between 55° and 55.5° C. during which time the auxograph tracing showed a retardation but not a stoppage of growth. The heat was shut off, the temperature soon falling to 42° C. and to 19° C. at 9 P.M., when the record assumed the character of that of the preceding day of the same joint and of a similar one standing near it.

A repetition of the tests was made next day at 10 A.M. when the joint stood at 33.5° C. The heaters were brought into action, the joint reaching 55° at 10:45 A.M. The preparation stood in the sun and was under normal conditions of ventilation and transpiration. Readings of 54.5° C. to 55.5° C. were made for a period of an hour and a half during which period the elongation was 0.2 mm. or near the maximum rate for the species and was still continuing. One heater was removed at 12:15 midday and ten minutes later the joint had fallen to 49.5° C. The cooling had resulted in a minute reverse movement of the auxograph recording lever of a character which could only be attributed to the contraction of the metal and clay of the setting. The temperature of the joints had fallen to 32° C. by 3 P.M. with no noticeable diminution of the rate, the maximum being taken to lie at some point over 40° C.

A comparison of the thermometer with U. S. Bureau of Standards No. 7618 gave an error so small as to be negligible with regard to the above data. Furthermore the young joint continued its growth at a rate normal to its developmental stage.

These and previously published measurements establish the following points:

1. Growth in *Opuntia* may begin at 9° C. and extend to 55° C.

2. Young joints of *Opuntia* may endure the maximum of 55° C. observed in mature joints in midsummer, for periods of an hour and a half, resuming elongation at lower temperatures with no perceptible after-effects.

3. A new high record for growth in *Opuntia* and for the higher plants of 55° C. (131° F.) has been established by these experiments.

4. The maximum rate of growth of *Opuntia* occurs between 37° C. and about 47°–49° C., under which conditions a biocolloid consisting of 9 parts agar and 1 part protein undergoes maximum swelling in water.[2]

5. The cell colloids of *Opuntia* include a large proportion of pentosans or mucilages, the colloidal condition of which is in general less affected by the temperatures used than albuminous substances. It is to be noted however that bacterial cells, which are highly albuminous, may withstand high tempera-

[1] MacDougal, D. T., and H. A. Spoehr, "Growth and Imbibition," *Proc. Amer. Phil. Soc.*, 56, 289–352, 1917. McGee, J. M., "The Effect of Position upon the Temperature and Dry Weight of Joints of *Opuntia*," Carnegie Inst. Wash. Year Book for 1916, p. 73. MacDougal, D. T., "Hydration and Growth," Carnegie Inst. Wash. Pub. 297, 1920. DeVries, H., "Matériaux p. l. connaisance d. l'influence d. l temperature s. l. plantes," *Arch. Néerlandaises*, III., p. 3, 1870.

[2] MacDougal, D. T., "The Relation of Growth and Swelling of Plants and Biocolloids to Temperature," *Proc. Soc. Exper. Biol.*, 15, 48–50, 1917.

tures, such as those of boiling water. The presence of salts or other compounds may be accountable for the resistance of the proteins to high temperatures.

D. T. MacDougal

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THE AMERICAN MATHEMATICAL SOCIETY

The two hundred and fourteenth regular meeting of the American Mathematical Society was held at Columbia University, on Saturday, February 26, 1921, extending through the usual morning and afternoon sessions. The attendance included thirty-five members Ex-president H. B. Fine occupied the chair. One hundred and fifteen new members were elected, and twenty-four applications for membership in the society were received.

The council voted to accept the invitation to affiliate with it extended to the society by the American Association for the Advancement of Science.

Professor E. B. Van Vleck was appointed representative of the society in the division of physical sciences of the National Research Council, to succeed Professor H. S. White. The final report of the committee on membership and sales was presented by its chairman, Professor E. R. Hedrick; in all one hundred and thirty-two applications for membership have been received through this very efficient committee. Questions having arisen concerning dues of foreign members, concerning sales and exchanges of publications with foreign societies and libraries, and concerning individual or concerted efforts to aid foreign journals, a committee was appointed by the council to consider these and related problems.

A letter was read to the council from ex-secretary F. N. Cole donating to the society the sum which accompanied the testimonial tendered him at the preceding meeting of the society in recognition of his very distinguished services. It was voted that the council accept the gift and extend to Professor Cole its heartiest appreciation of his generosity; it was further voted that this fund shall constitute, and be designated as, the Cole Fund. A committee was appointed to consider the use to which the income can best be devoted. The council approved the suggestion that the present volume of the society's *Bulletin* be inscribed to Professor Cole.

A letter of felicitation was sent to Professor Mittag-Leffler, of Stockholm, on the occasion of the seventy-fifth anniversary of his birth.

The following papers were read at this meeting:

Coefficient of the general term in the expansion of a product of polynomials: L. H. Rice.

The mathematical theory of proportional representation, with a substitute for least squares: E. V. Huntington.

On the apportionment of representatives: F. W. Owens.

On the polar equation of algebraic curves: Arnold Emch.

Generalization of the concept of invariancy derived from a type of correspondence between functional domains. Second proof of the finiteness of formal binary concomitants modulo p: O. E. Glenn.

Concerning the sum of a countable number of point sets: R. L. Moore.

On the simplification of the structure of finite continuous groups with more than one two-parameter invariant subgroup: S. D. Zeldin.

Periodic functions with a multiplication theorem: J. F. Ritt.

Note on equal continuity: J. F. Ritt.

Expressions for the Bernoulli function of order p: I. J. Schwatt.

The expansion of a continued product: I. J. Schwatt.

Method for the summation of a family of series: I. J. Schwatt.

Note on the evaluation of a definite integral: I. J. Schwatt.

A property of the Pellian equation with some results derived from it: John McDonnell.

A necessary and sufficient condition that the sum of two bounded, closed and connected point sets should disconnect a plane: Anna M. Mullikin.

Some empirical formulas in ballistics: T. H. Gronwall.

Summation of a double series: T. H. Gronwall.

A geometrical characterization of the paths of particles in the gravitational field of a mass at rest: L. P. Eisenhart.

The equations of interior ballistics: A. A. Bennett.

The next meetings of the society will be at Chicago on March 25 and 26, and at New York, in April.

R. G. D. Richardson,
Secretary